APPENDIX F

Muscoy Plume Front Extraction Well Technical Memorandum

MUSCOY PLUME
FRONT EXTRACTION WELL
TECHNICAL MEMORANDUM

MUSCOY PLUME OPERABLE UNIT
REMEDIAL DESIGN

Prepared for:

Contract No. 68-W9-0054 / WA No. 54-46-9J5N
U.S. Environmental Protection Agency
Region IX
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1.0 INTRODUCTION

This technical memorandum describes the extraction well location design of the Muscoy Operable Unit (OU) plume front extraction well system. Design of the system includes the location, number, and extraction rates of the proposed new extraction wells. The physical design of the extraction well system (e.g., casing diameter, screen interval and size, packing materials) will be completed when the pilot borings for the extraction wells are drilled. The project flow model (in conjunction with the existing boring and electric logs and geophysical survey results) was used as the basis for the extraction well system location and flow rates.

The Final Muscoy Plume OU Remedial Investigation/Feasibility (RI/FS) Report (URSG 1994) identified an extraction well system for the Muscoy plume: a new extraction well system consisting of four extraction areas near the maximum contaminant level (MCL) isoconcentration contour for tetrachloroethene (PCE). The extraction areas were along a northeast-southwest transect between the 19th Street and Baseline Feeder pumping facilities.

The current technical memorandum presents the results of additional evaluation and groundwater modeling conducted after the Final Muscoy Plume OU RI/FS Report was distributed. This latest modeling effort simulated combined pumping from the recently constructed Newmark South Facility Extraction Wells System (five newly installed extraction wells along 11th Street) and the proposed Muscoy Extraction Well System. Several different pumping scenarios were simulated to evaluate water transport and treatment facility logistics. The preferred extraction well system is presented in this technical memorandum. Three preliminary extraction well alternatives for the Muscoy Extraction Well system were evaluated along with six pipeline route alternatives in a previous technical memorandum (URSG 1997c).

This study is within the scope of Subtask 4.1 of the Muscoy Plume OU Remedial Design Work Assignment (No. 54-46-9J5N) under URSG Contract No. 68-W9-0054 with the U.S. Environmental Protection Agency (EPA).

1.1 OBJECTIVES

The objectives of this memorandum are to determine the following items:

- The location of the Muscoy extraction wells.
- The number of extraction wells.
- The pumping rates from the extraction wells.

1.2 BACKGROUND

The California Department of Health Services (DHS) discovered chlorinated solvents in the municipal supply wells within the northern San Bernardino/Muscoy region of San Bernardino County during a 1980 groundwater investigation. Several investigations were conducted to locate the potential source(s) of

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2.0 EXTRACTION WELL SYSTEM DESIGN

This section introduces three extraction well scenarios that were simulated using the project flow model. This section is divided into three subsections: (1) a brief description of the Muscoy groundwater contaminant plume; (2) a description of extraction scenarios considered in this memorandum; and (3) the results of the preferred extraction scenario model run.

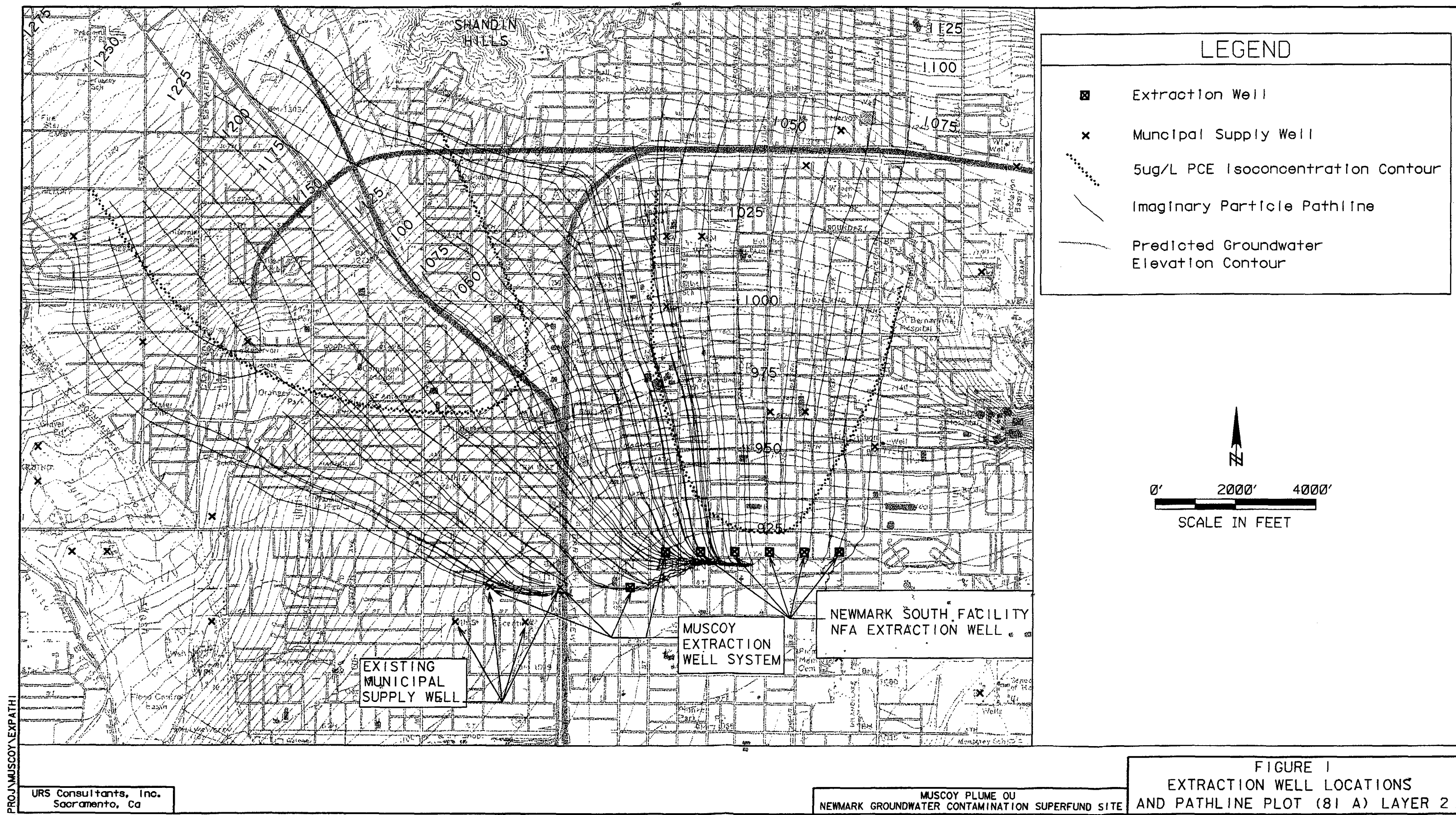## 2.1 MUSCOY GROUNDWATER CONTAMINANT PLUME

Figure 1 shows the approximate extent of the Muscoy groundwater plume. The extent of the plume is based on recent groundwater quality data obtained from the Long-Term Groundwater Monitoring and Sampling Program (URSG 1997a). The Newmark groundwater contaminant plume is also shown on the figure. Because the number of wells available to delineate the extent of the plume is limited, a conservative approach is used to interpret the data. A comparison of the recent analytical data from wells near the leading edge of the Muscoy plume show that contamination in the southern part of the Muscoy plume is generally restricted to a zone between 600 and 800 feet above mean sea level (URSG 1997a).

2.2 EXTRACTION SCENARIOS

Three extraction scenarios (and minor variations of these totaling 29 computer runs) were simulated during this modeling effort. Since the objective of the design was to select an extraction system with the optimum number, pumping rate, and location of wells, variations of these three parameters were used to devise the scenarios. The extraction wells were placed at the leading edge of the Muscoy groundwater plume in the vicinity of the $5\mu g/L$ isoconcentration contour for PCE to limit further downgradient contaminant migration above the PCE MCL ($5\mu g/L$). The simulated extraction wells were screened only in the lower aquifer (or layer two of the model). This was because contamination was identified in the lower aquifer near the Muscoy plume front. All of the scenarios were simulated with the Newmark extraction system operating at design capacity. The results, consequently, predict a combined effect from running both the Newmark and Muscoy extraction systems.

The three extraction well system scenarios evaluated are described below:

1. Muscoy extraction well system scenario 1 (model run 82a). This scenario includes five new extraction wells, each pumping at a rate of 1,300 gpm (total flow of 6,500 gpm), along the north side of Baseline Street.

LEGEND

⊠   Extraction Well

×   Muncipal Supply Well

⋯⋯   5ug/L PCE Isoconcentration Contour

╱   Imaginary Particle Pathline

╱   Predicted Groundwater Elevation Contour

0'   2000'   4000'

SCALE IN FEET

NEWMARK SOUTH FACILITY
NFA EXTRACTION WELL

MUSCOY
EXTRACTION
WELL SYSTEM

EXISTING
MUNICIPAL
SUPPLY WELL

MUSCOY PLUME OU
NEWMARK GROUNDWATER CONTAMINATION SUPERFUND SITE

FIGURE 1
EXTRACTION WELL LOCATIONS
AND PATHLINE PLOT (81 A) LAYER 2

PROJNMUSCOY.EXPATH!

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2.   Muscoy extraction well system scenario 2 (model run 76b). This scenario includes the use of two existing Water Department water supply wells and one new extraction well. The proposed capacity of each well is 2,500 gpm with a total flow of 7,500 gpm. The two existing Water Department water supply wells are at the Olive and Garner streets and the 10th and J streets locations. The new extraction well is proposed to be on 10th Street east of Interstate 215.

3.   Muscoy extraction well system scenario 3 (model run 81a). This scenario includes the use of the two existing Water Department water supply wells (Olive & Garner and 10th & J), and two new Muscoy extraction wells. One new Muscoy extraction well is proposed to be north of 10th Street (east of I-215) and the other is proposed to be on 11th Street about 800 feet west of the western-most newly-installed Newmark extraction well (EW1) (Figure 1). The proposed capacity is 2,5000 gpm for each of the existing Water Department water supply wells, and 1,300 gpm for each of the two new Muscoy extraction wells.

2.3   RESULTS OF THE EXTRACTION SCENARIOS

In order to improve model efficiency, to decrease scenario setup times, and to more efficiently revise the model, the computer hardware and software used to conduct the modeling for this project were upgraded. The model is currently implemented using an interactive computer program called the *Department of Defense Groundwater Modeling System (GMS©)* developed by Brigham Young University - Engineering Computer Graphics Laboratory. The entire *GMS©* system consists of a graphical user interface (the *GMS©* program) and a number of analysis codes (*MODFLOW* and *MODPATH* were used for this project). The graphical interface provides for efficient information sharing among different analysis codes. Graphics tools are also provided for site characterization, model conceptualization, grid generation, geostatistics, and post-processing. Use of *GMS©* drastically reduced the time necessary to develop model scenarios and process the results.

GMS© was developed to facilitate particle tracking in conjunction with groundwater flow modeling, a requirement for this project. The particle tracking code programmed for *GMS©* use is *MODPATH*. Once the project model was successfully imported into the *GMS©* environment, the *GMS©* run *MODFLOW* output was compared to the previous *MODFLOW* version output for the same model scenario. The two versions of *MODFLOW* output were compared to assure that no significant changes were created during import into the *GMS©* interface.

The particle tracking code used previously on this project was PATH3D©. PATH3D© was run under a different operating system than GMS©. The particle tracking code supported by *GMS©* is *MODPATH*. Similarly to the *MODFLOW* conversion, after the particle tracking model was converted to *MODPATH* and tested, the outputs from both particle tracking codes were compared to assure acceptability. *MODPATH* output was considered acceptable because no significant differences from the PATH3D© results were observed for the same model scenario.

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Each extraction scenario was simulated as follows:

- *MODFLOW* was run for each extraction scenario to simulate flow conditions for 35 years (or 4 stress periods per year for 140 periods) from January 1986 to December 2020.

- The results from *MODFLOW* runs were used as input to *MODPATH* to create imaginary particle pathlines.

- The output files from *MODFLOW* and *MODPATH* were processed in *GMS*© to produce plots of head contours, pathlines of imaginary particles, and locations of extraction areas.

To create imaginary pathlines, three sets of imaginary particles were used in *MODPATH*. Set no. 1 contained 15 imaginary particles that were placed along the upper-middle region of the Muscoy plume. Set no. 2 contained 31 imaginary particles that were placed in the middle region of the Muscoy and Newmark plumes. Set no. 3 contained 21 imaginary particles that were placed at the leading edge of the Muscoy plume and along the lower-middle region of the Newmark plume. Locations of the imaginary particles are listed in Table 1 and shown on the Figure 1.

The pathline of an imaginary particle produced by *MODPATH* represents predicted movement of groundwater in the aquifer over time. Because the contaminants (TCE and PCE) move with the groundwater, the imaginary particle pathline also represents the predicted movement of contaminants in the aquifer over time. The pathlines of the imaginary particles, therefore, represent the predicted movement of contaminants in the Muscoy Plume and Newmark OUs. The extraction scenarios were evaluated based on predicted capture of imaginary particles by the extraction wells. Pumping details and results of the extraction scenario simulations are presented below.

Table 2 summarizes the detail of twenty-nine model simulations. The preferred extraction scenario is model run 81a (scenario 3). Table 3 lists the extraction parameters for the three Muscoy extraction scenarios.

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Table 1

IMAGINARY PARTICLE LOCATIONS FOR EXTRACTION SCENARIOS

Particle(s)	Model Cell (j,i,k)	Particle(s)	Model Cell (j,i,k)
Set 1			
1	(11,33,2)	9	(15,29,2)
2	(12,33,2)	10	(16,29,2)
3	(12,32,2)	11	(16,28,2)
4	(13,32,2)	12	(17,28,2)
5	(13,31,2)	13	(17,27,2)
6	(14,31,2)	14	(18,27,2)
7	(14,30,2)	15	(18,26,2)
8	(15,30,2)		
Set 2			
16	(17,39,2)	32	(25,31,2)
17	(18,38,2)	33	(25,30,2)
18	(17,38,2)	34	(26,30,2)
19	(19,37,2)	35	(27,30,2)
20	(18,37,2)	36	(28,30,2)
21	(19,36,2)	37	(28,29,2)
22	(20,36,2)	38	(29,29,2)
23	(20,35,2)	39	(29,28,2)
24	(21,35,2)	40	(30,28,2)
25	(21,34,2)	41	(31,28,2)
26	(22,34,2)	42	(32,28,2)
27	(22,33,2)	43	(33,28,2)
28	(23,33,2)	44	(34,28,2)
29	(23,32,2)	45	(35,28,2)
30	(24,32,2)	46	(36,28,2)
31	(24,31,2)		

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Table 1 (Cont'd.)

IMAGINARY PARTICLE LOCATIONS FOR EXTRACTION SCENARIOS

Particle(s)	Model Cell (j,i,k)	Particle(s)	Model Cell (j,i,k)
		Set 3	
47	(22,41,2)	54	(25,37,2)
48	(22,40,2)	55	(25,36,2)
49	(23,40,2)	56	(26,35,2)
50	(23,39,2)	57	(26,34,2)
51	(24,39,2)	58	(27,33,2)
52	(24,38,2)	59	(28,33,2)
53	(25,38,2)	60	(29,33,2)
61	(30,33,2)	65	(34,33,2)
62	(31,33,2)	66	(35,33,2)
63	(32,33,2)	67	(36,33,2)
64	(33,33,2)		

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Table 2

SUMMARY OF MODEL RUNS

Runs	Objective(s)	Input Files Used and Revisions	Summary of Results
64a	1) Import project model into interactive modeling software (Department of Defense Groundwater Modeling System: *GMS*©v. 1.2)	1) Files were copied from run 63e to create this run.	1) Import was not fully successful. This run was used as basis for modifications to import model into *GMS*©.
65a	1) Import project model into interactive modeling software (Department of Defense Groundwater Modeling System: *GMS*© v. 1.2)	1) Files from run 64a were imported into *GMS*© v. 1.2 and saved. The evapotranspiration file was recreated in *GMS*© because file 64a.evt could not be successfully imported.	1) Import was not fully successful. This run was not used again.
66a	1) Import project model into *GMS*© v. 2.0.	1) Files from run 64a were imported into *GMS*© v. 2.0 and saved. The evapotranspiration file was recreated in *GMS*© because file 64a.evt could not be successfully imported. The well pumpage was based on a modified version of file 63a.wel with zero pumpage wells removed.	1) Well pumpage values were rounded to two significant figures in *GMS*©. 2) Model runs encountered memory conflicts and limitations in computer hardware. Changed computer operating system to Windows NT v. 3.51.
67a	1) Import project model into *GMS*© v. 2.0.	1) Files from run 66a were used. File 59j was imported into *GMS*© as pumpage values. 2) Recreated pumpages of run 59j as a new file in *GMS*© due to software-code-generated problems.	1) Well pumpage values still rounded by *GMS*© but importation problems apparently solved with recreation of well file.
67b	1) Import project model into *GMS*© v. 2.0.	1) Input files from run 67a. Modified well pumpages to simulate run 59j.	1) Well pumpage values still rounded. 2) *GMS*© rounded all well pumpage valves to two significant figures.

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SUMMARY OF MODEL RUNS

Runs	Objective(s)	Input Files Used and Revisions	Summary of Results

67bb	1) Import project model into *GMS*©v. 2.0.
	
	2) Simulate run 59J in *GMS*©.
		1) Input files from run 67b. Well pumpage values were modified to use values from run 59j.
		  - 19th St. #1 and #2 wells using actual pumpage for first five years and zero pumpage thereafter for both layers.
		  - 4 new extraction wells pumping
		    (35,25,1&2) 1,500 gpm
		    (37,23,1&2) 1,500 gpm
		    (39,21,1&2) 1,700 gpm
		    (40,19,1&2) 1,500 gpm
		  - No pumping from Baseline Street wells.
		
		2) *GMS* program modification eliminated pumpage value rounding.
			1) Simulation converged with 0% water balance discrepancy.
			2) Output duplicated run 59J.
			3) These input files can be used as baseline input file to incorporate extraction scenarios in future model runs.
			
			2) Well pumpage values were not rounded.

67c	1) Predict effect on plume with no extraction on east side of Interstate 215 along eastern portion of Muscoy plume front.	1) Input files from run 67BB. Added extraction well (35,25) at zero pumpage for layers 1 and 2.	1) Simulation converged with 0% water balance discrepancy.

68a	1) Predict effect on plume with extraction from five new wells at Muscoy plume front.	1) Input files from run 67BB. Added a fifth extraction well at cell 32,26.
		
		  - 5 new extraction wells pumping
		    (35,25,1&2) 1,500 gpm
		    (37,23,1&2) 1,500 gpm
		    (39,21,1&2) 1,700 gpm
		    (40,19,1&2) 1,500 gpm
		    (32,26,1&2) 1,000 gpm
		
		  - No pumping from Baseline Street wells.
			1) Simulation converged with 0% water balance discrepancy.
			2) Three of 54 imaginary particles remained active at the end of the model run.

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SUMMARY OF MODEL RUNS

Runs	Objective(s)	Input Files Used and Revisions	Summary of Results
69a	1) Predict effect on plume with extraction from four wells at Muscoy plume front with five Newmark extraction wells also pumping. Baseline Feeder wells were also added to the simulation based on historic pumpages.	1) Input files from run 67BB. 2) Added Newmark extraction wells - extraction wells pumping from layer 2 (40,30,2) 1,400 gpm (40,31,2) 1,100 gpm (40,32,2) 2,000 gpm (40,33,2) 1,100 gpm (40,34,2) 1,400 gpm 3) 17th Street well pumpage was changed from cyclical pumping to 1,400 gpm starting in January 1991 (stress period 21). 4) Pumpages for Baseline Feeder wells were historic values for 1991 through 1993. Pumpages were repeated for this three-year period through the end of run.	1) Simulation converged with 0% water balance discrepancy.
70a	1) Predict effect on plume with five Muscoy plume front wells in combination with Newmark and Baseline Feeder wells.	1) Input files from run 69A. 2) Added one Muscoy well (32,26,1&2). Ratio of pumping: Layer 1:2 = 0.33:0.67	1) Simulation converged with 0% water balance discrepancy.
70b	1) Predict effect on plume with five Muscoy plume front wells in combination with Newmark and Baseline Feeder wells.	1) Input files from run 70A. 2) All Muscoy pumping changed to layer 2 only.	1) Simulation converged with 0% water balance discrepancy.
71a	1) Predict effect on plume with four Muscoy plume front wells in combination with Newmark and Baseline Feeder wells.	1) Input files from run 70B. 2) Removed Muscoy wells from run 70B locations. 3) Added four new Muscoy wells (39,20,2) 1,500 gpm (39,22,2) 1,500 gpm (39,24,2) 1,700 gpm (37,26,2) 1,700 gpm	1) Simulation converged with 0% water balance discrepancy.

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SUMMARY OF MODEL RUNS

Runs	Objective(s)	Input Files Used and Revisions	Summary of Results
72a	1) Predict effect on plume with four Muscoy plume front wells in combination with Newmark and Baseline Feeder wells.	1) Input files from run 71A. 2) Deleted well at 37,26,2. 3) Added well at 39,26,2 pumping at 1,700 gpm.	1) Simulation converged with 0% water balance discrepancy.
73a	1) Predict effect on plume with four Muscoy plume front wells in combination with Newmark and Baseline Feeder wells.	1) Input files from run 72A. 2) Modified Newmark well locations and pumping. The locations better represent the actual locations in the field. (41,30,2) 1,700 gpm (41,31,2) 1,700 gpm (41,32,2) 2,000 gpm (41,33,2) 1,700 gpm (41,34,2) 1,700 gpm	1) Simulation converged with 0% water balance discrepancy.
73b	1) Predict effect on plume with four Muscoy plume front wells in combination with Newmark and Baseline Feeder wells.	1) Input files from run 73a. 2) Reduced pumping at two Muscoy wells (39,24,2) 1,500 gpm (39,26,2) 1,300 gpm	1) Simulation converged with 0% water balance discrepancy.
73a	1) Predict effect on plume with four Muscoy plume front wells in combination with Newmark and Baseline Feeder wells.	1) Input files from run 73b. 2) Reduced pumping in 41,32,2 to 1,500 gpm.	1) Simulation converged with 0% water balance discrepancy.
74A	1) Predict effect on plume with five Muscoy plume front wells in combination with Newmark and Baseline Feeder wells.	1) Input files from run 73c. 2) Increased pumpage in (41,32,2) to 1,860 gpm. 3) Added a well (39,28,2) pumping at 1,500 gpm.	1) Simulation converged with 0% water balance discrepancy.

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SUMMARY OF MODEL RUNS

Runs	Objective(s)	Input Files Used and Revisions	Summary of Results
74b	1) Predict effect on plume with five Muscoy plume front wells in combination with Newmark and Baseline Feeder wells.	1) Input files from run 74a. 2) Verified pumping at well (41,32,2) is 2,000 gpm. 3) Reduced pumping from Muscoy extraction wells from 1,500 gpm to 1,300 gpm for all Layer 2. 　　(39,20,2)　1,300 gpm 　　(39,22,2)　1,300 gpm 　　(39,24,2)　1,300 gpm 　　(39,26,2)　1,300 gpm 　　(39,28,2)　1,300 gpm	1) Simulation converged with 0% water balance discrepancy.
75a	1) Predict effect on plume with five Newmark wells in combination with Baseline Feeder wells and two existing Water Department (Olive & Garner and 10th & J) wells.	1) Input files from run 74a. 2) Removed all five Muscoy extraction wells. 3) Reduced Newmark well pumpages 　　(41,30,2)　1,400 gpm 　　(41,31,2)　1,100 gpm 　　(41,32,2)　2,000 gpm 　　(41,33,2)　1,100 gpm 　　(41,34,2)　1,400 gpm 4) Added two Water Department wells 　　(42,24,2)　2,000 gpm 　　(42,26,2)　2,000 gpm	1) Simulation converged with 0% water balance discrepancy. 2) This run did not capture all particles.

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SUMMARY OF MODEL RUNS

Runs	Objective(s)	Input Files Used and Revisions	Summary of Results
76a	1) Predict effect on plume with five Newmark wells in combination with Water Department wells and one new Muscoy extraction well.	1) Input files from run 75a. 2) Increased Newmark South well pumpages (41,30,2) 1,700 gpm (41,31,2) 1,700 gpm (41,32,2) 2,000 gpm (41,33,2) 1,700 gpm (41,34,2) 1,700 gpm 3) Reduced Baseline Feeder wells to 0 gpm (43,23,2) 0 gpm (43,25,2) 0 gpm 4) Increased Water Department wells pumpages (42,24,2) 2,500 gpm (42,26,2) 2,500 gpm 5) Added one new extraction well (42,28,2) 2,500 gpm	1) Simulation converged with 0% water balance discrepancy.
76b	1) Predict effect on plume with five Newmark wells in combination with Water Department wells and one new Muscoy extraction well.	1) Input files from run 76a. 2) Reduced pumpage from 7th Street well (44,34,2) to 0 gpm starting in stress period 21. Used actual pumpages for periods 0 through 20.	1) Simulation converged with 0% water balance discrepancy. 2) This run captured all but one particle. 3) Four of 67 imaginary particles remained active within the model run. All but 1 particle were not moving outside of their respective model cells and were considered stagnant.
76c	1) Determine if pumping at the 19th Street Pumping Facility affects Muscoy plume capture at the leading edge of the plume.	1) Input files from run 76a. 2) Added pumping at 19th #1 at maximum historical pumpages starting at stress period 21. Used actual pumpages for periods 0 through 20. (35,17,1) 1,150 gpm (35,17,2) 662 gpm	1) Simulation converged with 0% water balance discrepancy. 2) Plume capture at the leading edge of the Muscoy plume was not significantly affected by pumping from the 19th Street Pumping Facility.

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SUMMARY OF MODEL RUNS

Runs	Objective(s)	Input Files Used and Revisions	Summary of Results
76d	1) Determine if increased pumping at the 19th Street Pumping Facility affects Muscoy plume capture at the leading edge of the plume.	1) Input files from run 76a. 2) Increased pumpage at 19th #1 to 3,000 gpm total flow. 3) Added pumping at 19th #2 to 3,000 gpm starting at stress period 21. 19th #1 (35,17,1) 1,500 gpm 19th #1 (35,17,2) 1,500 gpm 19th #2 (35,17,1) 1,500 gpm 19th #2 (35,17,2) 1,500 gpm	1) Simulation converged with 0% water balance discrepancy.
77a	1) Determine if pumping at 9th & Garner well (Baseline Feeder) could help capture leading edge of Muscoy plume.	1) Input files from run 76a. 2) Added pumping at 9th & Garner of 3,000 gpm total starting at stress period 21. Proportioned pumpage over both layers per historical pumpage ratios. (43,23,1) 2,010 gpm (43,23,2) 990 gpm	1) Simulation converged with 0% water balance discrepancy. 2) 9th & Garner well is a high-TDS-producing well, so this well would not likely be used.
78a	1) Determine if pumping at 9th & Perris well could help capture leading edge of Muscoy plume.	1) Input files from run 77a. 2) Reduced pumping at 9th & Garner to 0 gpm. 3) Added pumping at 9th & Perris (43,25) of 3,000 gpm total starting at stress period 21 (Pumping for stress periods 0 - 20 was 0 gpm). Proportioned pumpage over both layers per historical ratios. (43,25,1) 1,800 gpm (43,25,2) 1,200 gpm	1) Simulation converged with 0% water balance discrepancy.

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SUMMARY OF MODEL RUNS

Runs	Objective(s)	Input Files Used and Revisions	Summary of Results
79a	1) Determine if pumping at both Baseline Feeder wells (9th & Garner and 9th & Perris wells) could help capture leading edge of Muscoy plume.	1) Input files from run 78a. 2) Added pumping at 9th & Garner of 3,000 gpm total starting at stress period 21. Proportioned pumpage over both layers per historical pumpage ratios. (43,23,1) 2,010 gpm (43,23,2) 990 gpm (43,25,1) 1,800 gpm (43,25,2) 1,200 gpm	1) Simulation converged with 0% water balance discrepancy.
80a	1) Determine if pumping at both Baseline Feeder wells (9th & Garner and 9th & Perris), two Water Department wells (Olive & Garner and 10th & J), and two new Muscoy extraction wells could capture leading edge of Muscoy plume.	1) Input files from run 79a. 2) Reduce new Muscoy extraction well (42,28,2) pumpage from 2,500 gpm to 1,300 gpm. 3) Add new well (41,29,2) pumping at 1,300 gpm. (42,24,2) 2,500 gpm (42,26,2) 2,500 gpm (43,23,1) 2,010 gpm (43,23,2) 990 gpm (43,25,1) 1,800 gpm (43,25,2) 1,200 gpm (42,28,2) 1,300 gpm (41,29,2) 1,300 gpm	1) Simulation converged with 0% water balance discrepancy. 2) Simulation adequately controlled Muscoy plume in combination with Newmark extraction system. 3) Although 4 of 67 imaginary particles remained active within the model run, all but 1 particle were not moving outside of their respective model cells and were considered stagnant.

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Table 2 (Cont'd.)

SUMMARY OF MODEL RUNS

Runs	Objective(s)	Input Files Used and Revisions	Summary of Results
80b	1) Determine if pumping at two Water Department wells (Olive & Garner and 10th & J) and two Muscoy extraction wells could capture leading edge of Muscoy plume.	1) Input files from run 80a. 2) Reduced pumpage in two Baseline Feeder wells from 3,000 gpm total for both layers to 0 gpm total for both layers. (43,23,1) 0 gpm (43,23,2) 0 gpm (43,25,1) 0 gpm (43,25,2) 0 gpm (42,24,2) 2,500 gpm (42,26,2) 2,500 gpm (42,28,2) 1,300 gpm (41,29,2) 1,300 gpm	1) Simulation converged with 0% water balance discrepancy. 2) Simulation adequately controlled Muscoy plume in combination with Newmark extraction system. 3) Although 34 of 67 imaginary particles remained active within the model run, all but 2 particles were not moving outside of their respective model cells and were considered stagnant.
81a	1) Determine if pumping at both Water Department wells (Olive & Garner and 10th & J) and two Muscoy extraction wells could help capture leading edge of Muscoy plume.	1) Input files from run 80b. 2) Used same pumpages from same wells. (42,24,2) 2,500 gpm (42,26,2) 2,500 gpm (42,28,2) 1,300 gpm (41,29,2) 1,300 gpm 3) Revised elevations of top of Layer 2 for several cells in model. 4) Model was run using GMS©v. 2.1 beta	1) Simulation converged with 0% water balance discrepancy. 2) Simulation adequately controlled Muscoy and Newmark plumes in combination with Newmark extraction system. This scenario is considered the working combined extraction scenario for both plumes. It uses two existing wells (Olive & Garner and 10th & J Water Department wells) in combination with two new Muscoy extraction wells and the 5 newly installed Newmark extraction wells. 3) Although 35 of 68 imaginary particles remained active during the model run, all but 2 particles were not moving outside of their respective model cells and were considered stagnant.

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Table 2 (Cont'd.)

SUMMARY OF MODEL RUNS

Runs	Objective(s)	Input Files Used and Revisions	Summary of Results
82a	1) Determine if pumping from five new Muscoy extraction wells located along the north side of Baseline Street will control Muscoy plume in combination with pumping from the five newly installed Newmark extraction wells.	1) Input files from run 81a. 2) Reduced pumping from Water Department wells (Olive & Garner and 10th & J) to 0 gpm. 3) Removed wells (42,28,2) and (41,29,2). 3) Created 5 new Muscoy extraction wells, all pumping at 1,300 gpm from Layer 2. 　(40,19,2)　1,300 gpm 　(40,21,2)　1,300 gpm 　(40,23,2)　1,300 gpm 　(40,26,2)　1,300 gpm 　(40,28,2)　1,300 gpm	1) Simulation converged with 0% water balance discrepancy. 2) All but 3 particles were captured. This model scenario appears to adequately capture both the Newmark and Muscoy plumes. The logistics of building 5 new Muscoy wells along with new pipelines make it a more expensive and challenging scenario.

Notes:

- All the runs were simulated for a period of 35 years from January 1986 through December 2020.
- New extraction wells were assumed to begin pumping from 6th year of simulation (i.e., pumping in extraction wells simulated for 30-years starting from January 1991 through December 2020).
- All the extraction runs included normal (or actual) pumping from 19th St. #1 and #2 wells for first 5-year period between January 1986 through December 1990.
- The Baseline Feeder wellfield includes the 9th & Garner and 9th & Perris San Bernardino Valley Municipal Water District wells.

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Table 3

**EXTRACTION SCENARIOS
FOR MUSCOY PLUME FRONT REMEDIAL DESIGN**

Model Run	Muscoy Extraction Scenario	Number of Extraction Wells	Pumping Rate	Total Pumping (gpm)
82a	No. 1	5	Each @ 1,300 gpm	6,500
76b	No. 2	3	Each @ 2,500 gpm	7,500
81a	No. 3	4	2,500; 2,500; 1,300; 1,300 gpm	7,600

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Figure 1 shows the groundwater head contours and pathlines of imaginary particles for Muscoy extraction scenario no. 3. Although 35 of 68 imaginary particles remained active during the model run, all but two particles were not moving outside of their respective model cells at the end of the run. Consequently, all but two of the imaginary particles were considered captured or stagnant. This extraction scenario appears to be effective in preventing further plume migration.

2.4   PROPOSED EXTRACTION WELL SYSTEM

Based on the model results, run 81a was chosen as the proposed extraction well system design. The proposed locations of the two new Muscoy extraction wells are shown on Figure 1. This scenario is most conducive to efficient water transfer with minimum new pipeline construction and relatively minimal groundwater pumping and treatment for the affected area. This scenario assumes that existing water supply wells at the Baseline Feeder Wellfield (9th & Garner and 9th & Perris wells) and the 7th Street well will not be operated for the duration of the remedial action (at least 30 years). Some of the municipal production wells in this region have pumping capacity as high as 3,000 gpm, or more. A pumping rate of 1,300 gpm is reasonable for this area based on nearby pumping from the Baseline Feeder Wellfield.

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3.0 CONCLUSIONS

Three extraction scenarios were evaluated with 29 model runs for their ability to capture imaginary particles using the project flow model. Based on this evaluation, model run 81a was chosen as the proposed extraction well system design. The proposed system consists of operation of two new Muscoy extraction wells about 1,160 feet apart along with operation of two existing Water Department wells (Olive & Garner and 10th & J Street water supply wells). The system also assumes that existing water supply wells at the Baseline Feeder Wellfield (9th & Garner and 9th & Perris wells) and the 7th Street well will not be operated at all. Each new well is proposed to pump at 1,300 gpm and the existing water supply wells are proposed to pump at 2,5000 gpm each (total system pumping at 7,600 gpm). The proposed locations of the new extraction wells are shown on Figure 1. The precise location of each well will depend on land accessibility.

It should be noted that the proposed extraction well system design is an estimate based on the project flow model, and therefore subject to the same uncertainty and limitations as the model. The following limitations particularly affect the well system design: (a) model grid spacing: the project flow model uses a grid spacing of 820 feet in the x and y directions. Because of the grid size, a minimum well spacing of 820 feet can be used in the model simulation. If smaller well spacings were used, a different extraction rate might effectively capture the imaginary particles; (b) extraction well screen lengths: the model does not allow for separate screened intervals within an aquifer or for partial penetration of an aquifer. Although the plume front appears to be shallower in the Muscoy plume than the Newmark plume, it is not present over the entire thickness of the aquifer. The model assumes extraction wells are fully penetrating over the entire model layer (layer 2). This difference could allow the model to predict a greater pumping rate than necessary. The proposed extraction wells will be screened over a portion of the lower aquifer to optimize plume capture. Actual pumping rates will be based on pumping tests performed on the newly constructed wells. Regardless, the design proposed is considered optimal based on the available data and the specific objectives of the system.

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